trade and 15 to 21 months for the SE. trade, and that this high surface temperature in some way brings about a high barometric pressure over the southern part of the region and a low pressure in the northern part, so that a high surface temperature in the North Atlantic gives rise to an abnormally steep barometric gradient from south to north.

Space does not permit touching upon the many phases of the subject considered. Ten major conclusions are presented as follows:

(1) The surface temperature of the North Atlantic Ocean between Florida and Valencia has a positive correlation with synchronous pressure over the area Valencia, Bergen, Berlin, and Azores, but a negative correlation with pressure at Jacobshavn and Stykkisholm.

(2) The pressure at Jacobshavn and Stykkisholm has a positive correlation with the NE. trade wind four months before, this relationship not being due to the influence of the Gulf Stream.

(3) The surface temperature of the North Atlantic has a positive correlation with the NE. trade wind 12 months before, this relationship being due to the influence of the Gulf Stream.

(4) The surface temperature has a negative correlation with the NE. trade wind 15 to 21 months before.

(5) The correlation between the pressure in western Europe and the North Atlantic and the strength of the NE. trade wind 12 to 21 months before is generally small, but the coefficients usually have the signs to be expected from relationships (1), (3), and (4); that is, pressure at stations in the area Valencia, Bergen, Berlin, and Azores tends to have a positive correlation with the NE. trade wind 12 months before, and a negative correlation with the trade wind 15 to 21 months before.

(6) The surface temperature of the North Atlantic has a positive correlation with the velocity of the SE. trade wind 15 to 21 months before, this relationship being due to the influence of the Gulf Stream.

(7) Pressure at Valencia, Paris, Berlin, and Ponta Delgada has a positive correlation with the velocity of the SE. trade wind 15 to 21 months before; pressure at Jacobshavn, Stykkisholm, and Vardo has a negative correlation with the velocity of the SE. trade wind 15 to 21 months before.

(8) The surface temperature of the North Atlantic and the pressure at Ponta Delgada have a positive correlation with the Bermuda-Charleston pressure difference 3 to 9 months before and 15 to 18 months before.

(9) The surface temperature of the North Atlantic has a positive correlation with the Bermuda-Sydney (Nova Scotia) pressure difference three months before; the pressure at Ponta Delgada has a small positive correlation, and pressure at Jacobshavn a small negative correlation with the Bermuda-Sydney pressure difference three months before.

(10) The pressure in Western Europe and the North Atlantic (except the Azores) has a negative correlation with the pressure difference three months before between the point 50° N., 20° W. and Vestmanno, Iceland. At the Azores the correlation is positive. —*A. J. H.*

IMPROVED WATER-FLOW PYRHELIOMETER

By W. M. SHULGIN, Scientific Collaborator and Lecturer

[Timiriaseff's Academy of Rural Economy, Moscow, U. S. S. R.]

Doctor Abbot in America has constructed a water-flow pyrheliometer, which appears to be the most accurate standard apparatus for the measurement of the intensity of solar radiation yet made. My work at the meteorological observatory of the Timiariaseff's Academy of Rural Economy, Moscow, has for its object the continuation of these studies of the pyrheliometer for the purpose of improving its construction and increasing its accuracy. I describe here a method that permits the intensity of solar radiation to be measured with an accuracy of 0.1 per cent or more, depending upon the sensitiveness of the galvanometer.

The theory of the apparatus constructed by Doctor Abbot, and described in the Annals of the Astrophyical Observatory of the Smithsonian Institution, Volume III, is quite simple. In order to attain high precision a flow of water at constant temperature at all points is indispensable. For this purpose there is required a thermostat which will allow only insignificant fluctuations of temperature, not exceeding 0.0001°. This thermostat should be located as near as possible to the entrance to the pyrheliometer, and then care must be taken that the water that passes it does not change temperature before reaching the calorimeter.

Numerous experiments convinced me that in the case of an open platform and an inserted tube such a thermostat is impracticable. I have therefore planned an improvement of the apparatus itself that will obviate the necessity of constant temperature of the flowing water.

I have investigated the necessity of constant temperature of the water during considerable periods and the objections to fluctuations in temperature.

I have reached the conclusion that under certain conditions variations in temperature of the water do not interfere with the accuracy of the apparatus.

Let us suppose that first of all we have obtained a constant temperature of the flowing water. Then the readings of our two thermoelements, one at the ingress and the other at the egress, will be zero. But suddenly a column of hot water appears at the ingress. (Fig. 1.) As soon as it reaches the ingress thermoelement the latter will receive a temperature increase of t_2-t_1, and the galvanometer will record t_2-t_1 (fig. 2) until the hot column leaves the ingress thermoelement. In Figure 3 it has nearly left it; in Figure 4 it is entirely separated from the ingress thermoelement, and the galvanometer again reads zero.

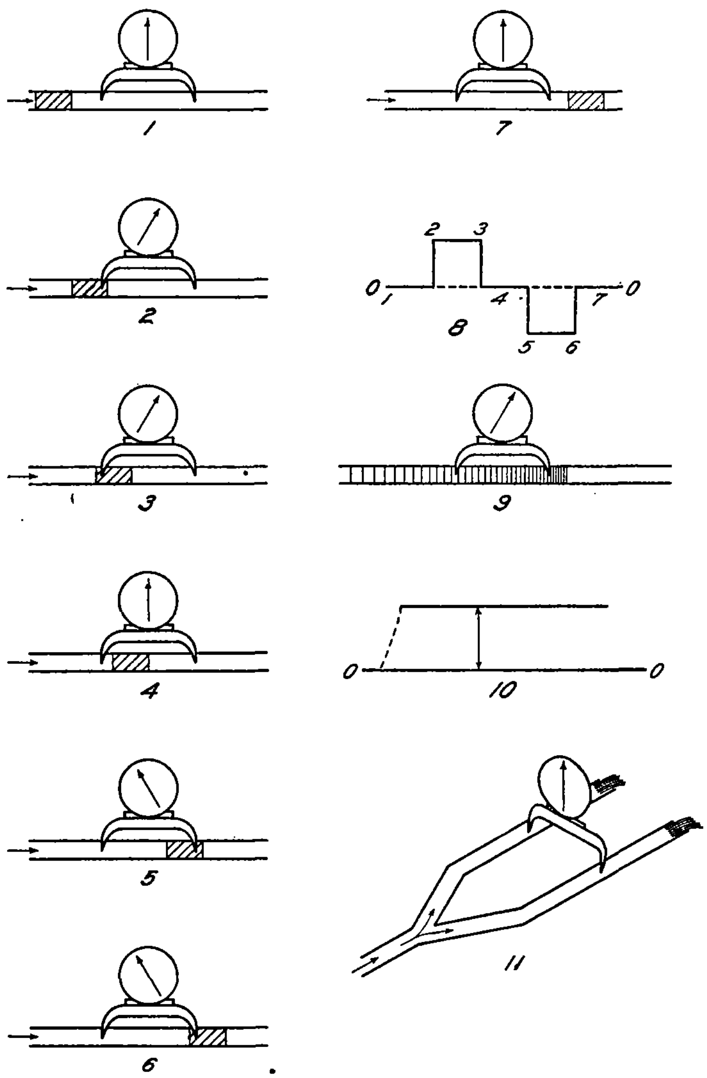
As it advances the hot-water column reaches the egress thermoelement, Figure 5, and the galvanometer is deflected by a current of the same strength as before, but having the opposite sign. The galvanometer again comes to the zero line when the hot-water column leaves the egress thermoelement, Figures 6 and 7.

The phenomena of the passage of a hot column in an ideal case (absence of inertia in the galvanometer, no loss of heat from the water column, etc.) are reproduced in the lines of Figure 8. During half a minute, the time required for the water column to traverse the tube, the recording galvanometer has inscribed two quite similar squares, but of opposite sign, the algebraic sum of the areas of which equals zero.

Actually we have no water columns with such sudden transitions from high to low temperature. The thing to be noted is that if the hot columns follow one another regularly and their temperatures are equal, then the sum of the squares recorded on the photogram and the sum of the heat received by the calorimeter during the half-minute interval are each equal to zero.

It can even happen that the hot columns will pass the thermoelements synchronously. Then the galvanometer will record a continuous straight line, without arches or depressions, notwithstanding the variations in the temperature of the water flow. Let us indicate the length of the spiral tube of the apparatus by L, the length of the cold column by l_1, the length of the hot column by l_2. Then evidently synchronism will obtain when $\frac{L}{l_1+l_2}=$ a whole number. Therefore regular variations in the temperature of the water flow do not cause errors in observations that extend over a period of more than half a minute.

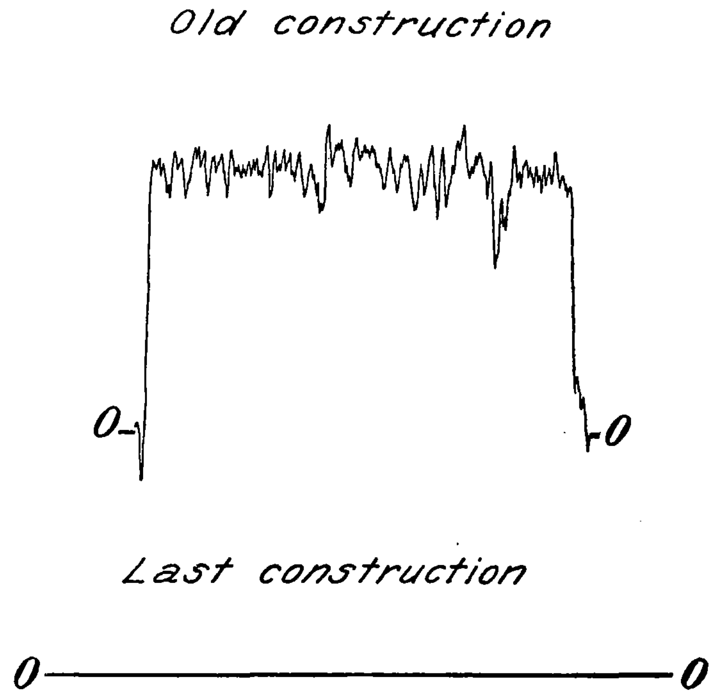
Quite a different result will be obtained if we have irregular temperature variations. Such variations are shown graphically in Figure 9, where the vertical lines indicate the temperature—the more numerous the lines the higher the temperature. Under these conditions the right-hand thermoelement will have the higher temperature and at no time will the record return to zero. Also the deviations of the galvanometer on the two sides of



zero will be unequal. On the other hand, during all this time the photogram will show increase of heat, although the waterflow that enters will continually be recorded as becoming colder. This sign of the ordinate, which in general is variable, I call the *tendency* of the *flow*. This tendency is recorded with great precision by my apparatus and in general indicated sources of error in the pyrheliometer. For instance, we may obtain a perfectly straight line a little above the zero, Figure 10, which does not mean at all that the flowing water received its heat in the calorimeter. It may mean that before entering the calorimeter the temperature of the water is unfailingly and regularly raised.

For the elimination of this temperature tendency from the records of the apparatus I had intended at first to use two spirals joined in the same Dewar vessel, which would require two galvanometers. Afterwards I worked out a method by means of which I exclude this temperature tendency of the water flow and attain a perfectly straight zero line, using only one galvanometer. The principle of the method is the following:

Let us assume a tube containing flowing water and divided into two branches, Figure 11. By means of Reynold's formula we may determine a section of the tubes that will prevent the formation of eddies. Therefore the water entering the branches will constitute two longitudinal flows of equal strength, and at the ends of the branches two points can be found where the temperature difference $t_2 - t_1$ always equals zero. These points will be found at equal distances from the place of branching, and they will be the points at which the thermal



elements will be placed. Then if one of the branches of the tube is warmed by the sun a difference of temperature will at once be indicated, as the temperature tend ency of the tube exposed to the sun is changed.

These theoretical considerations have been fully confirmed by experiments, as is seen from the photograms reproduced in Figure 12. Figure 12, upper part, shows a four-hour record made by apparatus of the old type with a thermostat placed in the path of flow. Figure 12, lower part, shows a record of more than five hours' duration constructed with a branching tube and without a thermostat. The water entered the apparatus from a plain Mariott's bottle.

Verifying the apparatus by means of a Dgaul's heater, I obtained figures deviating $=0.1$ per cent from the mean, but I propose further improvements in construction, following the method of branching flow developed by me, provided my material means permit.